Letters to the Editor.

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The Law of Inertia for Radiating Masses.

RADIATION of amount δE, lost by a body, diminishes its effective mass, on Maxwellian principles, by $\delta E/c^2$: and some perplexity is apparent in recent discussion as to how this tells on the dynamical inertia of a planetary mass. According to the Newtonian doctrine, it is the rate of change of momentum mv which must be equated to the extraneous gravitational or electric force acting on the body: and this principle was taken over by Einstein, in extended fourfold form and in concert with relativity, as the key to his brilliant tentative explorations towards a closer view of gravitation. But

$$\frac{d}{dt}(mv) = m\frac{dv}{dt} + v\frac{dm}{dt};$$

so that if the mass is diminishing by radiation, conservation of momentum seems to demand acceleration of velocity of a body isolated and so free from external force. Yet the doctrine of relativity asserts that no standard can exist on which to measure such change of velocity, whether of translation or rotation: such a conclusion therefore would contradict relativity. On this ground it is claimed that the applied force must be equated, following Dr. Jeans, to $m\frac{dv}{dt}$ and not to $\frac{d}{dt}(mv)$. Yet the latter form is based directly on a very keystone of relativity. One way out of the apparent paradox would be to postulate a frame in the ether with reference to which the velocity of an isolated body could be measured: this would institute an exception to accepted doctrine widely verified. Prof. E. W. Brown (*Proc. U.S. National Academy*, 1926, p. 2) appears to be troubled, and naturally so, by uncertainty as to which formula to adopt with a view to studies on cumulative long-range effects of radiation in dynamical astronomy.

It seems well worth while, in this connexion, to direct attention to a classical memoir by the late Prof. Poynting (*Phil. Trans.*, 1903) on "Radiation in the Solar System" and to his other investigations, theoretical and experimental, on pressure of radiation, in which astronomical effects are considered. In particular, he revealed (by indirect argument) what amounts to the Bradley aberration effect in pressure of extraneous radiation on a moving body: and he showed that it produces a retarding force that would in times quite short geologically suck all small bodies such as cosmical dust revolving steadily round the sun, into that luminary. This is doubtless the explanation, as he remarked, why the celestial spaces are so transparent. Incidentally it may perhaps require that the cosmic dust that reflects the zodiacal light should have some source of replenishment.

This, however, is not directly connected with the inertia question. But in the reprint of Poynting's "Collected Papers" (Cambridge University Press, 1920), the question of the effect of diminution of inertia by radiation had to be gone into, in the notes and corrections then appended to the work, as on the face of things it may be quite comparable in importance (for large masses) to the deflexion of the radiation pressure by aberration. The explanation proceeds on the principles of Maxwell's great "Treatise" of 1873, without any reference to relativity. It is in effect verified (pp. 434, 754-7, referring back to "Math. Congress Report," Cambridge, 1912) that the momentum of the whole system, matter *plus* radiation, is conserved, as it ought to be, in the absence of any extraneous force; but a part of its gradient equal to $v\frac{dm}{dt}$, where $\delta m = -\delta E/c^2$, is momentum carried away by the radiation δE issuing from the system, by the mechanism of radiation pressure, while it is the remainder $m\frac{dv}{dt}$ that is to be equated to the extraneous force, which acts on the material system itself, not on the radiation that has escaped from it.

This seems to be the adequate practical settlement of this question, and may, it is hoped, encourage Prof. Brown to proceed with closer astronomical investigations in improvement of Poynting's pioneer indications: though how far it consorts with an extreme relativist position is a different question. But Poynting's retardation by the aberration influence on pressure of radiation will also have to be taken into account in the cosmical problem of the evolution of the orbits of a double star, as probably of the same degree of importance as change of effective mass by loss of radiant energy.

In Poynting's own special problem there is no change of mass (other than that involved in high velocity in accordance with Least Action), as the loss by radiation is made good by absorption from the sun.

JOSEPH LARMOR.

Cambridge, February 9.

The Structure of Molecules.

WITHIN the past few months there have appeared several papers on band spectra containing results of great theoretical significance. Taken in connexion with the data given in my letter to NATURE of February 13, p. 229, on the energy levels of the carbon monoxide molecule, they appear to indicate a comprehensive analogy between the electronic energy levels of molecules and of atoms. The additional evidence furnished by the rotation and vibration of molecules then makes possible conclusions as to the actual paths of the valence electrons in molecules, and these results may in turn be used as evidence as to the structure of atoms.

Some of the investigations leading up to this situation are as follows. Mulliken (*Phys. Rev.*, 26, 561, 1925) has shown clearly the existence of two types of multiplicity in the band spectra given by diatomic molecules. One type is essentially a function of the rotation of the two nuclei about their common centre of gravity, and has no counterpart in atomic structure. It is not concerned in the present discussion. The other type is essentially independent of rotation and of vibration, and, as Mulliken has pointed out, leads to multiple electronic energy levels in the molecule which may be correlated with the multiple levels of atoms. Thus in the "odd" molecules CO^+, BO, CN, and NO, there is a double level which may be designated as a double "p" level. Mulliken (*Phys. Rev.*, 26, 1, 1925) has found such a double level also in the alkaline earth halides, and has noted that the doublet separation is of the same order of magnitude as in a certain "corresponding" atom, having the same number of valence electrons. Mecke (*Naturwiss.*, 13, 698 and 755, 1925) independently pointed out certain analogies between BO, CO^+, CN, and N_2^+, and investigated also the alkaline earth